Refine Search

Search Results -

Term	Documents
WATER	3723243
WATERS	76474
ETHYLENE	667847
ETHYLENES	3000
GLYCOL	481189
GLYCOLS	125877
(17 AND ((ETHYLENE ADJ GLYCOL) OR WATER)).PGPB,USPT,USOC,EPAB,JPAB,DWPI,TDBD.	19
(L17 AND (WATER OR (ETHYLENE ADJ GLYCOL))).PGPB,USPT,USOC,EPAB,JPAB,DWPI,TDBD.	19

Database:
US Pre-Grant Publication Full-Text Database
US Patents Full-Text Database
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Derwent World Patents Index
IBM Technical Disclosure Bulletins

Search: L22

Refine Search

Recall Text Clear Interrupt

Search History

DATE: Thursday, August 19, 2004 Printable Copy Create Case

Set Name side by side	**Query**	**Hit Count**	**Set Name** result set
	DB=PGPB,USPT,USOC,EPAB,JPAB,DWPI,TDBD; PLUR=YES; OP=ADJ		
L22	L17 and (water or (ethylene adj glycol))	19	L22
L21	L20 and (switch$4)	7	L21
L20	L19 and (shield$4)	8	L20

L19	L18 not L13	13	L19
L18	L17 and (flat$4 or planar or pancake or open or thermal$2 or heat$4 or temperature)	26	L18
L17	L11 and ((magnetic adj resonance) or MRI or NMR)	30	L17
L16	L15 and ((magnetic adj resonance) or MRI or NMR)	1	L16
L15	L14 and (switch$4)	6	L15
L14	L13 and (shield$4)	17	L14
L13	L12 and (flat$4 or planar or pancake or open or thermal$2 or heat$4 or temperature)	26	L13
L12	L10 and (transvers$4 with (gradient or coil))	29	L12
L11	L9 and (transvers$4 with (gradient or coil))	58	L11
L10	L9 and (helix or helical$2 or spiral$2)	44	L10
L9	L8 and ((hollow or tube or cylindrical or cylinder or tubular) with (strip or tape or ribbon or conduct$4 or electric$4 or section))	110	L9
L8	L7 and ((flow$4 or moving or move or movement or motion or movable or moved or pass or passing or passed) with (fluid$3 or water or coolant or liquid))	195	L8
L7	L6 and (flow$4 or moving or move or movement or motion or movable or moved or pass or passing or passed)	416	L7
L6	L5 and (wound or winding or coiled or looped)	434	L6
L5	L4 and (strip or tape or ribbon or conduct$4 or electric$4)	870	L5
L4	L3 and (fluid$3 or water or coolant or liquid)	951	L4
L3	L2 and (transvers$4)	1522	L3
L2	L1 and (hollow or tube or cylindrical or cylinder or tubular)	4541	L2
L1	(gradient with coil)	9747	L1

END OF SEARCH HISTORY

Hit List

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Search Results - Record(s) 1 through 19 of 19 returned.

1. Document ID: US 20040140800 A1

Using default format because multiple data bases are involved.

L22: Entry 1 of 19 File: PGPB Jul 22, 2004

PGPUB-DOCUMENT-NUMBER: 20040140800
PGPUB-FILING-TYPE: new
DOCUMENT-IDENTIFIER: US 20040140800 A1

TITLE: Nuclear magnetic resonance apparatus and methods for analyzing fluids extracted from earth formation

PUBLICATION-DATE: July 22, 2004

INVENTOR-INFORMATION:

NAME	CITY	STATE	COUNTRY	RULE-47
Madio, David P.	Danbury	CT	US	
Kleinberg, Robert L.	Ridgefield	CT	US	
Gaylor, Richard W.	Brookfield	CT	US	
Freedman, Robert	Houston	TX	US	

US-CL-CURRENT: 324/303; 324/306

Full | Title | Citation | Front | Review | Classification | Date | Reference | Sequences | Attachments | Claims | KWIC | Draw De

2. Document ID: US 20010015646 A1

L22: Entry 2 of 19 File: PGPB Aug 23, 2001

PGPUB-DOCUMENT-NUMBER: 20010015646
PGPUB-FILING-TYPE: new
DOCUMENT-IDENTIFIER: US 20010015646 A1

TITLE: Cooled NMR probe head with uniform temperature control of the sample

PUBLICATION-DATE: August 23, 2001

INVENTOR-INFORMATION:

NAME	CITY	STATE	COUNTRY	RULE-47
Marek, Daniel	Moeriken		CH	

US-CL-CURRENT: 324/321; 324/318

Full | Title | Citation | Front | Review | Classification | Date | Reference | Sequences | Attachments | Claims | KWIC | Draw D

3. Document ID: US 6496007 B1

L22: Entry 3 of 19 File: USPT Dec 17, 2002

US-PAT-NO: 6496007
DOCUMENT-IDENTIFIER: US 6496007 B1
**** See image for Certificate of Correction ****

TITLE: MRI apparatus

DATE-ISSUED: December 17, 2002

INVENTOR-INFORMATION:

NAME	CITY	STATE	ZIP CODE	COUNTRY
Damadian; Jevan	East Northport	NY		
Linardos; John	Smithtown	NY		
Danby; Gordon T.	Wading River	NY		
Damadian; Raymond V.	Woodbury	NY		

US-CL-CURRENT: 324/318; 600/415

Full | Title | Citation | Front | Review | Classification | Date | Reference | | | Claims | KWIC | Draw D

4. Document ID: US 6489872 B1

L22: Entry 4 of 19 File: USPT Dec 3, 2002

US-PAT-NO: 6489872
DOCUMENT-IDENTIFIER: US 6489872 B1

TITLE: Unilateral magnet having a remote uniform field region for nuclear magnetic resonance

DATE-ISSUED: December 3, 2002

INVENTOR-INFORMATION:

NAME	CITY	STATE	ZIP CODE	COUNTRY
Fukushima; Eiichi	Albuquerque	NM		
Jackson; Jasper A.	Albuquerque	NM		

US-CL-CURRENT: 335/299; 335/216

Full | Title | Citation | Front | Review | Classification | Date | Reference | | | Claims | KWIC | Draw D

5. Document ID: US 6469508 B1

L22: Entry 5 of 19 File: USPT Oct 22, 2002

US-PAT-NO: 6469508
DOCUMENT-IDENTIFIER: US 6469508 B1

TITLE: MRI apparatus

DATE-ISSUED: October 22, 2002

INVENTOR-INFORMATION:

NAME	CITY	STATE	ZIP CODE	COUNTRY
Damadian; Jevan	East Northport	NY		
Linardos; John	Smithtown	NY		
Danby; Gordon T.	Wading River	NY		
Damadian; Raymond V.	Woodbury	NY		

US-CL-CURRENT: 324/318; 324/322

Full | Title | Citation | Front | Review | Classification | Date | Reference | | | Claims | KWIC | Draw De

6. Document ID: US 6445186 B1

L22: Entry 6 of 19 File: USPT Sep 3, 2002

US-PAT-NO: 6445186
DOCUMENT-IDENTIFIER: US 6445186 B1

TITLE: MRI apparatus

DATE-ISSUED: September 3, 2002

INVENTOR-INFORMATION:

NAME	CITY	STATE	ZIP CODE	COUNTRY
Damadian; Jevan	East Northport	NY		
Linardos; John	Smithtown	NY		
Danby; Gordon T.	Wading River	NY		
Damadian; Raymond V.	Woodbury	NY		

US-CL-CURRENT: 324/319; 324/320

Full | Title | Citation | Front | Review | Classification | Date | Reference | | | Claims | KWIC | Draw De

7. Document ID: US 6437570 B2

L22: Entry 7 of 19 File: USPT Aug 20, 2002

US-PAT-NO: 6437570
DOCUMENT-IDENTIFIER: US 6437570 B2

TITLE: Cooled NMR probe head with uniform temperature control of the sample

DATE-ISSUED: August 20, 2002

INVENTOR-INFORMATION:

NAME	CITY	STATE	ZIP CODE	COUNTRY
Marek; Daniel	Moeriken			CH

US-CL-CURRENT: 324/321; 324/300, 324/322

Full | Title | Citation | Front | Review | Classification | Date | Reference | | | Claims | KWIC | Draw D

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8. Document ID: US 6400980 B1

L22: Entry 8 of 19 File: USPT Jun 4, 2002

US-PAT-NO: 6400980
DOCUMENT-IDENTIFIER: US 6400980 B1

TITLE: System and method for treating select tissue in a living being

DATE-ISSUED: June 4, 2002

INVENTOR-INFORMATION:

NAME	CITY	STATE	ZIP CODE	COUNTRY
Lemelson; Jerome	Incline Village	NV	89451	

US-CL-CURRENT: 600/478; 600/104, 604/22

Full | Title | Citation | Front | Review | Classification | Date | Reference | | | Claims | KWIC | Draw D

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9. Document ID: US 6369571 B1

L22: Entry 9 of 19 File: USPT Apr 9, 2002

US-PAT-NO: 6369571
DOCUMENT-IDENTIFIER: US 6369571 B1

TITLE: MRI apparatus

DATE-ISSUED: April 9, 2002

INVENTOR-INFORMATION:

NAME	CITY	STATE	ZIP CODE	COUNTRY
Damadian; Jevan	East Northport	NY		
Linardos; John	Smithtown	NY		
Danby; Gordon T.	Wading River	NY		
Damadian; Raymond V.	Woodbury	NY		

US-CL-CURRENT: 324/318; 324/319

Full | Title | Citation | Front | Review | Classification | Date | Reference | Claims | KWIC | Draw De

10. Document ID: US 6335623 B1

L22: Entry 10 of 19 File: USPT Jan 1, 2002

US-PAT-NO: 6335623
DOCUMENT-IDENTIFIER: US 6335623 B1
**** See image for Certificate of Correction ****

TITLE: MRI apparatus

DATE-ISSUED: January 1, 2002

INVENTOR-INFORMATION:

NAME	CITY	STATE	ZIP CODE	COUNTRY
Damadian; Jevan	East Northport	NY		
Linardos; John	Smithtown	NY		
Danby; Gordon T.	Wading River	NY		
Damadian; Raymond V.	Woodbury	NY		

US-CL-CURRENT: 324/320; 324/319

Full | Title | Citation | Front | Review | Classification | Date | Reference | Claims | KWIC | Draw De

11. Document ID: US 6275039 B1

L22: Entry 11 of 19 File: USPT Aug 14, 2001

US-PAT-NO: 6275039
DOCUMENT-IDENTIFIER: US 6275039 B1

TITLE: Magnetic resonance pre-polarization apparatus

DATE-ISSUED: August 14, 2001

INVENTOR-INFORMATION:

NAME	CITY	STATE	ZIP CODE	COUNTRY
Young; Ian Robert	Marlborough			GB
Eastham; John Frederick	Bath			GB

US-CL-CURRENT: 324/319; 324/300, 324/306, 324/307, 324/309, 324/318

Full | Title | Citation | Front | Review | Classification | Date | Reference | Claims | KWIC | Draw De

12. Document ID: US 5886548 A

L22: Entry 12 of 19 File: USPT Mar 23, 1999

US-PAT-NO: 5886548
DOCUMENT-IDENTIFIER: US 5886548 A

TITLE: Crescent gradient coils

DATE-ISSUED: March 23, 1999

INVENTOR-INFORMATION:

NAME	CITY	STATE	ZIP CODE	COUNTRY
Doty; F. David	Columbia	SC		
Wilcher; James K.	Columbia	SC		

US-CL-CURRENT: 324/318

Full | Title | Citation | Front | Review | Classification | Date | Reference | Claims | KWIC | Draw D

13. Document ID: US 5757187 A

L22: Entry 13 of 19 File: USPT May 26, 1998

US-PAT-NO: 5757187
DOCUMENT-IDENTIFIER: US 5757187 A

TITLE: Apparatus and method for image formation in magnetic resonance utilizing weak time-varying gradient fields

DATE-ISSUED: May 26, 1998

INVENTOR-INFORMATION:

NAME	CITY	STATE	ZIP CODE	COUNTRY
Wollin; Ernest	Leesburg	FL		

US-CL-CURRENT: 324/306; 324/318

Full | Title | Citation | Front | Review | Classification | Date | Reference | Claims | KWIC | Draw D

14. Document ID: US 5642087 A

L22: Entry 14 of 19 File: USPT Jun 24, 1997

US-PAT-NO: 5642087
DOCUMENT-IDENTIFIER: US 5642087 A

TITLE: Generating highly uniform electromagnetic field characteristics

DATE-ISSUED: June 24, 1997

INVENTOR-INFORMATION:

NAME	CITY	STATE	ZIP CODE	COUNTRY
Crow; James T.	Albuquerque	NM		

US-CL-CURRENT: 335/216; 324/318, 335/299

Full | Title | Citation | Front | Review | Classification | Date | Reference | | | Claims | KWIC | Draw D

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15. Document ID: US 5304933 A

L22: Entry 15 of 19 File: USPT Apr 19, 1994

US-PAT-NO: 5304933
DOCUMENT-IDENTIFIER: US 5304933 A

TITLE: Surgical local gradient coil

DATE-ISSUED: April 19, 1994

INVENTOR-INFORMATION:

NAME	CITY	STATE	ZIP CODE	COUNTRY
Vavrek; Robert M.	Waukesha	WI		
Myers; Christopher C.	Milwaukee	WI		

US-CL-CURRENT: 324/318; 324/300

Full | Title | Citation | Front | Review | Classification | Date | Reference | | | Claims | KWIC | Draw D

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16. Document ID: US 5233991 A

L22: Entry 16 of 19 File: USPT Aug 10, 1993

US-PAT-NO: 5233991
DOCUMENT-IDENTIFIER: US 5233991 A
**** See image for Certificate of Correction ****

TITLE: Method and apparatus for estimating oxygen saturation of blood using magnetic resonance

DATE-ISSUED: August 10, 1993

INVENTOR-INFORMATION:

NAME	CITY	STATE	ZIP CODE	COUNTRY
Wright; Graham A.	Palo Alto	CA		

US-CL-CURRENT: 600/410; 600/419

Full | Title | Citation | Front | Review | Classification | Date | Reference | | | Claims | KWIC | Draw D

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17. Document ID: US 5212447 A

L22: Entry 17 of 19 File: USPT May 18, 1993

US-PAT-NO: 5212447

DOCUMENT-IDENTIFIER: US 5212447 A

TITLE: Apparatus and technique for NMR diffusion measurement

DATE-ISSUED: May 18, 1993

INVENTOR-INFORMATION:

NAME	CITY	STATE	ZIP CODE	COUNTRY
Paltiel; Zvi	Ness Ziona			IL

US-CL-CURRENT: 324/300; 324/303

Full | Title | Citation | Front | Review | Classification | Date | Reference | Claims | KWIC | Draw De

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18. Document ID: US 4516404 A

L22: Entry 18 of 19 File: USPT May 14, 1985

US-PAT-NO: 4516404
DOCUMENT-IDENTIFIER: US 4516404 A

TITLE: Foam filled insert for horizontal cryostat penetrations

DATE-ISSUED: May 14, 1985

INVENTOR-INFORMATION:

NAME	CITY	STATE	ZIP CODE	COUNTRY
Laskaris; Evangelos T.	Schenectady	NY		

US-CL-CURRENT: 62/51.1; 220/901

Full | Title | Citation | Front | Review | Classification | Date | Reference | Claims | KWIC | Draw De

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19. Document ID: US 4475084 A

L22: Entry 19 of 19 File: USPT Oct 2, 1984

US-PAT-NO: 4475084
DOCUMENT-IDENTIFIER: US 4475084 A

TITLE: Nuclear magnetic resonance detector

DATE-ISSUED: October 2, 1984

INVENTOR-INFORMATION:

NAME	CITY	STATE	ZIP CODE	COUNTRY
Moore; William S.	Mapperley Park			GB2
Hawkes; Robert C.	Bramcote			GB2
Holland; Geoffrey N.	Chagrin Falls	OH		

US-CL-CURRENT: 324/309; 324/307

Full | Title | Citation | Front | Review | Classification | Date | Reference | | | Claims | KWIC | Draw D

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Term	Documents
WATER	3723243
WATERS	76474
ETHYLENE	667847
ETHYLENES	3000
GLYCOL	481189
GLYCOLS	125877
(17 AND ((ETHYLENE ADJ GLYCOL) OR WATER)).PGPB,USPT,USOC,EPAB,JPAB,DWPI,TDBD.	19
(L17 AND (WATER OR (ETHYLENE ADJ GLYCOL))).PGPB,USPT,USOC,EPAB,JPAB,DWPI,TDBD.	19

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L22: Entry 12 of 19 File: USPT Mar 23, 1999

DOCUMENT-IDENTIFIER: US 5886548 A
TITLE: Crescent gradient coils

Abstract Text (1):
A high-conductivity ceramic coil form with an internal water jacket is used to simplify water cooling for 3-axis MRI gradient coil configurations on a single cylindrical coilform. Crescent-shaped, axially aligned coils are symmetrically employed on either side of the axial symmetry plane to increase transversely the region of field linearity. These crescent coils may be used in conjunction with Golay-type coils for improved switching efficiency. Lead-filled copper tubing may be used to reduce acoustic noise from pulsed coils in high external magnetic fields.

Brief Summary Text (2):
The field of this invention is electromagnetic coils for the purpose of efficiently generating gradients, especially in magnetic resonance imaging (MRI) and other gradient techniques employing a superconducting magnet.

Brief Summary Text (4):
Most modern MRI systems use a superconducting solenoid to establish a uniform B.sub.0 (or B.sub.Z) over the imaging volume. This results in the magnetic field being collinear with the path available for sample access. Coils are then required to produce monotonic, (preferably linear) gradients in B.sub.Z with respect to x, y, and z over the sample region during precisely determined pulse sequences. The transverse gradients (.delta.B.sub.Z /.delta.x, .delta.B.sub.Z /.delta.y) in the prior art have generally been established by symmetrically located sets of saddle coils, similar to those first described by Golay in U.S. Pat. No. 3,569,823 or by related planar coils as disclosed by Roemer, U.S. Pat. No. 4,926,125 and Morich et al, U.S. Pat. No. 5,036,282. Maxwell pairs or related geometries are universally used to generate the axial gradient. A co-pending application, Ser. No. 07/912,149, discloses the use of coil geometries more complex than surface currents to achieve order-of-magnitude improvements in several critical parameters for transverse gradient coils: acoustic noise and DC gradient efficiency.

Brief Summary Text (5):
The instant application discloses (a) the combined use of Golay-type and crescent-coil geometries for greatly improved switching efficiency and (b) the convenience of internal water cooling with transverse gradients. The closest prior art to the instant invention, in terms of magnetic field configuration, appear to be the trapezium loops for use with an electromagnet, as disclosed in the article "Magnetic Field Gradient Coils for NMR Imaging" by Bangert and Mansfield in Journal Physics, E, 15, 235 (1982), some screening concepts disclosed by Mansfield in U.S. Pat. No. 4,978,920, and the above referenced co-pending patent application.

Brief Summary Text (6):
The gradient pulses induce eddy currents and vibrations in nearby conducting structures (especially in flimsy shields, in the cryostat, and in lightweight rf coils) which perturb the field homogeneity following the pulses with time and spatial dependencies that are not easily characterized. Actively shielded coils for MRI were first publicly disclosed by Mansfield in February 1986 at approximately

the same time that Roemer filed the patent application which resulted in U.S. Pat. No. 4,737,716. Prior independent work was underway at Doty Scientific, which shipped the first such commercially available NMR gradient coils in January 1987. Actively shielded dipolar coils for energy storage were previously disclosed by Westendorp, U.S. Pat. No. 3,671,902. Actively shielded, constant-gradient, quadrupolar magnetic field coils based on cylindrical current sheets for atomic beam confinement and focusing were previously disclosed by Beth, U.S. Pat. No. 3,466,499.

Brief Summary Text (8):
The major gradient design problems center on the following: (1) limited available space because of economic considerations, (2) motion-induced artifacts arising from the finite stiffness and mass of the coil support structure, (3) practicable coil winding (or etching) techniques, (4) acoustic noise abatement, (5) heat dissipation, and (6) minimization of transverse field components.

Brief Summary Text (9):
The conflicting technical requirements may be partially addressed by means of local planar gradient coils with highly nonlinear response, as disclosed by Roemer, U.S. Pat. No. 4,926,125. By adding distortion correction algorithms to the image processing, it is possible to use gradients with .+-.40% to .+-.60% non-linearity on one axis in applications where high spatial resolution is required only over a small portion of the image.

Brief Summary Text (10):
The following parameters generally need to be specified for gradient coil systems: gradient coefficient .alpha. (T/Am) (sometimes called gradient efficiency in the prior art), imaging sphere diameter d.sub.i (m) for a specified linearity deviation, inductance L (H), resistance R.sub.E (.OMEGA.) maximum continuous power dissipation P (W), maximum pulse current I.sub.P (A) in a specified B.sub.0, recovery time T.sub.D (s) for a specified pulse, acoustic noise for a specified pulse sequence in a specified field, and ratio of transverse field energy in the sample region to axial field energy in the imaging region.

Brief Summary Text (11):
For the fastest imaging technique, Echo Planar Imaging (EPI) and related techniques, the most important parameters are recovery time, gradient switching efficiency, transverse fields, and acoustic noise. Although EPI was first described more than 15 years ago, it has seldom been used because prior art gradient coils (a) may require megawatts of gradient driver power on the frequency-encoding axis, (b) generate sound pressure levels that are painful and damaging to the patient's hearing, (c) produce motion-related artifacts that cannot be fully removed even with the most sophisticated image postprocessing, and (d) require high power audio amplifiers costing up to several million dollars. A recent experimental demonstration at 0.5 T required nearly half a megawatt (at 10% duty cycle) at 1 kHz, and others have proposed the use of 2 MW at 5 kHz, 1.5 T, and 50% duty cycle for slice-interleaved EPI techniques. The above problems may be partially addressed using a tuned transverse gradient with sinusoidal (monochromatic) current; but the conventional gradient coil has very low electrical Q; and there are penalties in SNR and heat dissipation. Also, computational analysis becomes more complex, but the software is available.

Brief Summary Text (12):
While the Maxwell z-gradient is considerably more efficient than the Golay transverse gradient, the frequency-encoding gradient must be in the plane of the image, which often must be transverse for medical reasons. Therefore, improvements are needed in transverse gradients.

Brief Summary Text (14):
It should be pointed out that there is ambiguity in the definition and usage of the

term "linearity" in the MRI gradient literature. Henceforth, we use this term to indicate the rms deviation of local field slope compared to the mean field slope over a specified volume. This definition is generally more demanding and a better indicator of image quality than the more common definition where linearity is defined as the maximum gradient field deviation relative to a linear field at any point in the sample, as the latter definition averages local fluctuations along the gradient axis. Other definitions can be less demanding and less useful.

Brief Summary Text (15):
The availability of better image processing and distortion correction techniques suggests that the rms gradient deviation a be increased to 14%, compared to the more typical 10% value for many prior art gradients, to increase imaging volume. It is still important that the field be monotonic, but the method of Schenck et al in U.S. Pat. No. 4,646,024 results in relatively poor switching efficiency, intolerable acoustic noise, and unmanageable motion-related artifacts.

Brief Summary Text (17):
In practice, using conventional shielded gradient coils, the inductive energy (I.sup.2 L/2) is larger than suggested by simple energy estimates by a substantial factor. In a co-pending patent application, methods are disclosed that allow increases in .alpha..sup.2 /L by factors of 2 to 10 compared to prior art Golay coils. However, for large systems the most important efficiency figure-of-merit often is .eta..sub.s =.alpha..sup.2 d.sub.i.sup.4 h.sub.i /.mu..sub.0 L, where h.sub.i is the imaging region field-of-view in the axial direction. The instant invention allows increases in .eta..sub.S by factors of 2 to 20 compared to prior art.

Brief Summary Text (18):
Some prior gradient coil designs have also suffered under the false notion that there is an inherent advantage with very low inductance coils. Higher inductance (more turns) requires higher voltage, but not higher power (VA) for the same switching time. In fact, reducing inductance below 100 .mu.H is detrimental as lead inductance and transmission line problems then becomes significant. Coil orthogonality (for isolation) and net force cancellation both dictate that integral number of turns be used in all coil sets and coil subsets. Hence, the accuracy of the shielding is limited from this quantization. The more turns, the more precisely the gradients can be shielded. Optimum number of turns is thus determined largely by the VA characteristics and economics of available power devices, magnetic shielding accuracy requirements, and standard wire insulation practice, making 250 V to 800 V (peak differential voltages for a balanced line) at 20 A to 300 A best for large systems. Optimum inductance is typically 0.2 to 1 mH.

Brief Summary Text (20):
A high-conductivity ceramic coil form with an internal water jacket is used to simplify water cooling for 3-axis MRI gradient coil configurations on a single cylindrical form. Crescent-shaped, axially aligned coils are symmetrically employed on either side of the axial symmetry plane to increase transversely the region of field linearity. These crescent coils may be used in conjunction with Golay-type coils for improved switching efficiency. Lead-filled copper tubing may be used to reduce acoustic noise from pulsed coils in high external magnetic fields.

Drawing Description Text (2):
FIG. 1 illustrates the prior-art, shielded, fingerprint, transverse gradient coil in the spherical coordinate system;

Drawing Description Text (3):
FIG. 2 discloses a tapered crescent coil with two parallel windings of lead-filled copper tubing;

Drawing Description Text (4):

FIGS. 3a and 3b illustrate a method of winding a coil on a coilform that has a concave surface;

Drawing Description Text (5):
FIGS. 4a and 4b disclose a transverse gradient coil system using a Golay coil and three axially oriented crescent coils on each side;

Drawing Description Text (6):
FIG. 5 depicts the use of an internal water cooling jacket;

Drawing Description Text (7):
FIGS. 6a and 6b illustrate a preferred 3-axes gradient coil assembly with an internal water cooling jacket;

Drawing Description Text (8):
FIG. 7 is a schematic representation of a method of connecting parallel windings to achieve orthogonality;

Drawing Description Text (9):
FIG. 8 is a schematic representation of a method of achieving orthogonality using gradient coils with shared windings;

Drawing Description Text (10):
FIG. 9 is a cross section of an X-Y gradient coil system using a Golay coil and twelve axially oriented crescent coils;

Drawing Description Text (11):
FIG. 10 is a schematic representation of a method of orthogonally powering 12 crescent coils with shared windings; and

Detailed Description Text (2):
Qualitative comparisons of various gradient coil geometries of different sizes are often misleading because of the complex expressions for power, inductance, resistance, and gradient coefficient and the varying degrees of sensitivity to coil motion. For example, power is often proportional to the radius to the fifth power for constant winding thickness and voxel size, but power is often linear with radius for constant number of voxels and constant relative winding thickness, depending on the relative significance of .gamma.Gd.sub.i T.sub.2 and SNR (signal to noise ratio) in the determination of spatial resolution. Here, .gamma. is the magnetogyric ratio, G is the magnetic field gradient (T/m), d.sub.i is the imaging diameter, and T.sub.2 is the spin-spin relaxation time (s). Thus, it is useful to develop dimensionless figures of merit for comparison of various gradient coil systems of various sizes.

Detailed Description Text (3):
We define a switching figure-of-merit, or switching efficiency, .eta..sub.S : ##EQU1## where .alpha. is the gradient coefficient (T/Am), d.sub.i is the imaging diameter for 14% rms gradient deviation .sigma., h.sub.i is the axial imaging length for the same deviation, .mu..sub.0 is the permeability of free space, and L is the inductance. The above definition differs from a previously derived definition by a constant, making it more conveniently expressed as a percent. For a typical ellipsoidal imaging region, it has numeric value between 1% and 20% for shielded Golay coils and 15% to 90% for shielded Maxwell pairs and quadrupolar coils for use in magnets with transverse B.sub.0.

Detailed Description Text (4):
Prior-art fingerprint coils as shown in FIG. 1 have typical .eta..sub.S of 10% to 30%, depending primarily on the shielding ratio to gradient radii. The crescent-Golay geometry disclosed in the current application achieves .eta..sub.S of 20% to 90%.

Detailed Description Text (5):
It should be noted that the gradient field produced by Golay or fingerprint coils is predominately in the radial direction near window 101, positioned close to polar angle .theta. of 45.degree.. This transverse component is of no imaging value, but it is responsible for the majority of the currents induced in the sample, which are to be minimized for patient safety reasons. Largely for this reason, and to enhance rf efficiency, it is not practical for d.sub.i to exceed 1.7r.sub.g, where r.sub.g is the gradient coil radius, as the induced currents increase rapidly for larger values of d.sub.i.

Detailed Description Text (6):
Next we define a low frequency (LF) electrical efficiency .eta..sub.L : ##EQU2## where the constant has the units m/s as indicated. This definition differs from an earlier definition by a constant factor, primarily for convenience. This LF efficiency evaluates to 2.5% for a typical prior-art transverse coil designed for d.sub.i =84 mm (the copper thickness was about half the skin depth) but values below 1% are typical for large planar transverse gradient coils. Typical values for Maxwell-pairs are near 10%, and there is usually little justification for higher LF efficiency, although values above 40% can be achieved for transverse gradients with octopolar geometries of the co-pending application and crescent-Golay systems of the current application.

Detailed Description Text (7):
The figure of merit governing coil power dissipation during EPI is Q.eta..sub.S, but the electrical Q at the switching frequency (e.g., 1600 Hz) cannot easily be determined, except by experimental measurement. The electrical Q is generally proportional to coil volume and the square root of frequency. For shielded whole-body coils at 1600 Hz it is typically 3 to 30.

Detailed Description Text (8):
Optimum conductor thickness in the fingerprint coil in regions where the gradient field is predominately axial is approximately one skin depth (typically 3 mm for copper) at the EPI switching frequency. However, optimum thickness in the vicinity of the window, where large radial components are present, is greater.

Detailed Description Text (9):
Coil motion is one of the most troublesome design limitations in many prior art gradient coils. Golay-type transverse gradient coils in a uniform external magnetic field develop opposite torques which cause the cylindrical coilform to bow in the plane of the z-axis and the desired gradient. The governing equations change radically depending on whether most of the energy in the gradient pulse spectrum is below or above the fundamental mechanical mode to which it is strongly coupled.

Detailed Description Text (11):
where t.sub.g is the gradient pulse length (s), s is the ##EQU3## difference between the shield coil radius and the gradient coil radius (m), and m.sub.c is the Golay coil mass per quadrant (kg). Clearly, relative mechanical energy during short pulses (electrical excitation frequency high compared to mechanical resonances) is minimized by increasing .eta..sub.S, s, and m.sub.c for a given B.sub.0 and t.sub.g. Since m.sub.c would be expected to increase as the second or third power of r.sub.g, it might appear that motion-related problems are reduced by increasing r.sub.g. However, t.sub.g (if inversely proportional to the gradient field strength, B.sub.G) will generally increase as the second, third, or even fourth power of r.sub.g in large coils, depending on the severity of acoustic noise and the amount of power that can be justified. Thus, electro-mechanical efficiency in the short-pulse limit typically increases with r.sub.g because the pulse lengths must increase. For the Golay-crescent geometry of the instant invention, the constant in the denominator is increased by a factor of four.

Detailed Description Text (13):
The co-pending patent application Ser. No. 07/912,149 discloses the mechanical advantages of small-diameter, solenoidal-like trapezoidal coils external to the imaging region for reducing acoustic problems. By increasing the stiffness, it is then possible to stay below resonance for the strongest couplings, and motion problems are easily eliminated. Also, the trapezoidal coil structures can achieve higher switching efficiency but linearity is inferior unless novel winding densities similar to those of the instant invention are used. The co-pending patent application also discloses that improved switching efficiency and improved shielding can be obtained by interleaving Golay-type coils with trapezoidal solenoidal coils.

Detailed Description Text (14):
According to equation [3], coilform stiffness is not a factor above resonance. Mechanical energy is decreased by simply increasing the mass of the coil. Hence, lead-filled copper tubing can be advantageous when the driving frequency is greater than a mechanical resonance. However, there will always be circumstances in which the coils are driven below mechanical resonance. Thus, it is desirable to mount massive conductors on stiff coilforms so that mechanical efficiency is poor at both low and high frequencies.

Detailed Description Text (15):
A simple method of quantifying shielding effectiveness is to define flux leakage .PHI..sub.L as the relative change in inductance when a passive cylindrical shield is added at radius r.sub.S, the radius of the radiation shields in the cryomagnet. This radius will typically be 1.2 (r.sub.g +s). ##EQU4## The above definition has only limited validity, as it does not distinguish between the various field dependencies. The eddy currents are far more sensitive to zero-order and first-order fields than to the high-order fields. The co-pending patent application Ser. No. 07/912,149 discloses dynamic compensation of the low-order eddy currents.

Detailed Description Text (16):
FIG. 2 discloses the crescent coil of the instant invention, which allows substantial improvements in switching efficiency, linearity, and shielding when used with Golay-type coils, especially when s is small compared to r.sub.g. Moreover, these improvements are achieved without significant increase in acoustic noise compared to the solenoidal geometries. The thick-walled, crescent coilform 201 is made of a high-modulus, non-magnetic material of high electrical resistivity such as glass-filled polyphthalamide (PPA) or a sialon. The crescent coilform 201 comprises a cylindrical concave surface 202, a cylindrical convex surface 203, radial surfaces 204, 205, and end surfaces 206, 207. The two cylindrical surfaces are concentric and subtend similar azimuthal angles .phi. with respect to a common axis 208, but the convex surface 203 will typically have greater axial length than that of the concave surface 202 and may subtend a somewhat larger or smaller azimuthal angle .phi.. The radial surfaces and end surfaces 204, 205, 206, 207 are trapezoidal in shape and may be inclined with respect to the radial direction. The radial surfaces may be slightly convex to facilitate coil winding. The axially oriented edges 211, 212, 213, 214 are radiused to simplify coil winding, and grooves 215 and lips 216 may be added to the arcuate and radial surfaces for the same purpose.

Detailed Description Text (17):
Two parallel coil windings 220, 221 are shown as would be required in some cases, but single windings and multiple-layer windings would often be preferred. For moderately large systems, lead-filled copper tubing may be used for the conductor elements, where each conductor 220, 221 is filled with lead 222. The increased density of Pb is beneficial in reducing acoustic noise and vibrations of the low-frequency transverse modes, according to equation [3]. In very large systems, the radial modes of the crescents could be more troublesome, in which case aluminum

strip or tubing would be preferred for the windings. Always, the windings would be securely bonded to the crescent coilform, preferably using a fiber-reinforced thermosetting material, such as epoxy or polyester 223. The crescent is symmetric with respect to a reflection through a plane 224 containing an internal coilform axis.

Detailed Description Text (18):
Novel fixturing is required to wind a coil on a coilform with a concave surface. The technique illustrated in FIGS. 3a and 3b attaches a cylindrical convex-convex spacer 301 to the concave surface 203 that can be removed by etching, melting, dissolving, disassembly, or mechanical machining after the coil is wound. The convex winding elements 323 near the concave surface may then be bent inward and bonded to the concave surface 202. The optimum winding density will always be higher on the concave surface than on the convex surface 203, and it will often be desirable to use two layers on the concave surface and a single layer on the convex surface, which may require a separate winding fixturing operation for each layer. For very large crescent coils, a more convenient approach than winding may be to solder individual segments of properly curved strips or tubing together. Then, different conductor element sizes can be used on the different surfaces.

Detailed Description Text (19):
Another method of producing the required winding on a concave surface would be to start by coating the entire external surface of the crescent coilform with copper film by sputtering, chemical vapor deposition, chemical precipitation, or any other suitable technique. A polymer resist can then be applied and developed by conventional screening or photochemical processes to permit etching of the desired winding or windings. The copper windings can then be electrochemically plated to the desired thickness.

Detailed Description Text (20):
FIG. 4 depicts a thin-walled, nonmetallic, cylindrical coilform 401 of approximate outer radius r.sub.g on which a hybrid y-gradient (.delta.B.sub.Z /.delta.y) coil assembly of the instant invention is mounted. The hybrid coil assembly subtends azimuthal angle .phi..sub.T greater than 110.degree. and less than 150.degree., on each side of the x-z plane. Golay coil 410 has first azimuthal members 411 at mean polar angle .theta..sub.1 between 48.degree. and 60.degree. and second azimuthal members 412 at mean polar angle .theta..sub.2 less than 42.degree.. In FIG. 4, Golay coil 410 appears twice, once in plain view at the left of coil form 401, and again in phantom behind the coil form 401. The latter is shown with its upper winding portions (azimuthal members) 412 and with lower winding portions. The upper winding portions have a center which defines polar angle .theta..sub.2, shown in phantom when obscured by coil form 401 and by part of winding portions 412. The lower winding portions, which mirror region 411 in the figure, have a center which defines polar angle .theta..sub.1.

Detailed Description Text (22):
The crescents have concave conductor elements 421 at approximate radius r.sub.g, convex conductor elements 422 at approximate radius r.sub.g +s, and radial conductor elements 423 therebetween.

Detailed Description Text (24):
The axial length h.sub.1 on the concave side of the crescents (See FIG. 2) is greater than r.sub.g /2 and less than 1.5r.sub.g. The axial length h.sub.2 on the convex side of the crescents is greater than 1.2h.sub.1 but less than 2.5h.sub.1. Numerical integration of the Biot-Savart law may be used to optimize windings for various values of s/r.sub.g and various optimization criteria. The surface current density on the concave side of the center crescent is typically about 40% greater than that on the diagonal crescents. Surface current densities on the convex sides of the crescents are typically lower near their ends than near the center. Surface current densities on the concave sides of the crescents are often 20% higher near

their ends than near the center. Surface current densities in the Golay coils are typically about 20% higher than the highest current densities in the crescents.

Detailed Description Text (25):
Since the crescent conductor elements form complete loops and are symmetrically inclined with respect to the uniform external field B.sub.0, there are no net Lorentz forces or torques on the center-of-mass of any of the crescents to first order. Thus, it is not necessary to be concerned about torsional or positional rigidity of the crescents in the gradient assembly. It is sufficient that the crescent coilforms be made of a material of high modulus to insure that the radial-mode mechanical resonances in the crescents are not excited. The crescents may then be precisely secured in position by epoxy bonding the concave surfaces of the crescents to the surface of the cylindrical coilform 401 without undue concern about rigidity of this cylinder. The elastic modulus of coilform 401 can be as low as 3 GPa in some cases, but elastic modulus above 200 GPa would be preferred for large systems in high B.sub.0 to minimize motion-related problems from the Golay coils at low frequencies.

Detailed Description Text (26):
Forced air cooling over the surfaces of the crescents and Golay coils will often provide sufficient cooling, but in some applications additional cooling will be required. FIG. 5 depicts an effective method of achieving higher power density by providing the benefits of water cooling with fewer of the electrical isolation and plumbing problems associated with conventional water cooling methods. (One prior art technique is to bond plastic plumbing to the surface of the fingerprint coils. Another prior-art technique is to hermetically coat all conductors and then flood the coil assembly with water. Another prior art technique is to use copper tubing for the coils and circulate deionized water directly through the live windings). The thin-walled coilform 401 is made from a material having high thermal conductivity and high strength, preferably silicon nitride, or alumina, or an alumina-filled composite. An inner thin-walled cylinder 501 of inner radius r.sub.1 and outer radius r.sub.2 is used to establish an internal cooling water jacket. O-rings 502, 503 may be used for compliant sealing, and plastic plumbing 504 can be used to circulate water through the annular space between the concentric cylinders. The Golay coil 410 bonded to the outer surface of the coilform is easily cooled by conduction. The crescents 420, 430, 440 are well cooled on their concave surfaces, and the high thermal conductivity of the heavy copper windings will usually conduct sufficient heat for adequate cooling of the other surfaces of the crescents. Both forced air cooling and water cooling may be used, allowing more flexibility in the use of the coils. The use of high-modulus, high-strength materials, allows the total relative thickness, (r.sub.g -r.sub.1)/r.sub.g, to be less than 0.1.

Detailed Description Text (27):
It will normally be desirable to mount the X, Y, and Z gradients on a single coilform of approximate radius r.sub.g as shown in a perspective view in FIG. 6a and in a cross section of the plus-plus quadrant of the yz plane in FIG. 6b. Note that x-Golay coil 610 and y-Golay coil 615 overlap and that diagonal crescents 620, 630, 640 are used for both the x and y axes. The x-Golay coil 610 and the y-Golay coil 615 are essentially identical except that one is positioned at .phi.+90.degree. relative to the other. Clearly, one is also at a slightly larger radius; the z position may also be shifted slightly. Conventional, corrected Maxwell pairs 660 are wound over the Golay coils for the z gradient. The internal water jacket 505 effectively cools all of the windings. Some simplification in the winding of the outer Golay coil (and perhaps some improvement in the cooling of the outer Golay coil) may be obtained by adding spacer material 611, equal in thickness to that of the inner Golay coil, to the surface of the coilform 401 beyond the azimuthal extent of the inner Golay so that the outer Golay has a substantially smooth, cylindrical surface on which to be mounted. For best heat transfer without eddy current problems, this spacer material would consist of a large number of open-ended segments of copper wires.

Detailed Description Text (28):
Optimum positions of external shielding coils 661 for the quadrupolar z-gradient may be determined by the method of Beth, U.S. Pat. No. 3,466,499, or by numerical application of the Biot-Savart law, or by other well-known methods. The octopolar fields produced by the Golay-crescent transverse gradient coils have extremely low external fields, but further shielding Golay coils 616 may still be desired. (Note that these coils are not shown in the isometric view). Numerical application of the Biot-Savart law is most practical for calculating gradient fields, leakage flux, and total inductance (from the total magnetic energy).

Detailed Description Text (29):
There are two general methods of orthogonally powering the diagonal crescents. In the first method, the center crescents each have one winding and the diagonal crescents each contain two sets of parallel windings, one set for each transverse axis. Each center crescent would typically have current density 40% greater than that of a single one of the windings on a diagonal crescent. This method has the advantage that each axis requires only one power amplifier. The x-amplifier drives the two crescents on the x-axis and one of the winding sets on each of the four diagonal crescents. The y-amplifier drives the two crescents on the y-axis and the other winding set on each of the diagonal crescents. One possible schematic representation of this approach is shown in FIG. 7. Here, each winding set consists of a single, full-length winding; the +z ends of the crescents are shown with dots, and all of the windings are counterclockwise when viewed from the +z end. In this case, the center crescents L.sub.C are in series with paralleled diagonal crescents L.sub.D, but many other series-parallel arrangements can be devised that produce the desired current densities and maintain orthogonality--that is, result in zero mutual inductance between the axes. The Golay coils are most conveniently wired in series with the crescents on each axis, as it is difficult to accurately calculate the separate inductances, but they can be paralleled with the crescents if the individual and mutual inductances can be accurately determined and matched along with proper resistance match. Of course, the fourfold symmetry allows simple parallel arrangements of the four quadrants with all coils per quadrant in series.

Detailed Description Text (30):
In the second general method, each diagonal crescent has only one winding set that is shared by both axes, but four power amplifiers are required to drive the transverse axes. For purposes of illustration, the four amplifiers are assumed to have equal transconductance and the crescents have equal turns densities. This approach has the advantages of simplified crescent windings and interconnections, easier impedance matching, reduced interwinding capacitance, and higher efficiency. One possible schematic representation to this approach is shown in FIG. 8 using the same conventions as used in FIG. 7. Again, many series-parallel variations are possible that achieve the desired surface current densities on the crescents. The X and Y signals are summed before being fed into the X+Y amplifier, and their difference is fed into the X-Y amplifier. While such a configuration requires a minimum of five amplifiers for an X-Y-Z gradient system compared to three for conventional designs, this approach would often be less expensive in large systems, where amplifier cost is primarily determined by total power. The amplifiers for the center crescents would require higher power rating and perhaps higher output impedance than the diagonal gradient amplifiers since the Golay coils would be connected in series with the center crescents. The voltages driving the diagonal crescents and the diagonal turns densities may, of course, be multiplied by any convenient factor to allow the use of amplifiers of more convenient impedances at the different power levels while achieving the desired relative current densities. In large systems, eight amplifiers would usually be used in a balanced configuration.

Detailed Description Text (32):
FIG. 9 is a cross section through the z=0 plane of an X-Y gradient coil system

using 12 crescents. In general, 4n crescents may be used, where n is an integer and the azimuthal current densities in the distributed crescents approximate that of a sine function. For 12 crescents centered at azimuthal positions .phi.=0.degree., 30.degree., 60.degree., 90.degree., 120.degree., 150.degree., . . . , the y-current density at 60.degree. and 120.degree. is approximately 87% of that at 90.degree. and the y-current density at 30.degree. and 150.degree. is approximately half that at 90.degree.. For the case of twelve or more crescents azimuthally, it becomes impractical to achieve the desired current densities on both axes through multiple windings driven by one amplifier per axis in a similar manner to that shown in FIG. 7. However, the method of FIG. 8 using a single winding per crescent can easily be extended to any number of crescents.

Detailed Description Text (34):
The crescent concept as a means of confining magnetic flux may be extended to more complex geometries with some additional improvement in both switching efficiency and shielding effectiveness but with increased complexity in the Biot-Savart numerical optimization, the manufacturing of the coilform, and in the coil winding or etching process. FIG. 11 shows one such extension of the crescent concept. The external concave cylindrical surface is symmetrically stepped to form a mid-external concave cylindrical surface 1120 with radius r.sub.g and two symmetrically located end-external concave cylindrical surfaces 1121, 1122 at radius r.sub.g +.epsilon., where .epsilon. is small compared to r.sub.g, so that the azimuthal windings on surfaces 1121, 1122 may overlap other coils on system coilform 401 at these axial locations. For example, it may be desirable to have a Z gradient winding 140 in this location to improve the linearity of the Z gradient. In such case of a Z gradient 1141 would desirably fit in stepped area 1126 and 1127. The external convex cylindrical surface may also be symmetrically stepped to form a mid-external convex cylindrical surface 1125 at radius r.sub.g +s and two symmetrically located end-external convex cylindrical surfaces 1126, 1127 at radius r.sub.g +s-.epsilon.. The crescent ends include annular sectors 1131, 1132, on which are mounted end-azimuthal conductors. Portions of hyperbolic surfaces of revolution 1133, 1134 join the end annular sectors to the end-concave cylindrical surfaces. Among the surfaces with azimuthal current conductors, the mean surface current density would be highest on the end-external concave cylindrical surfaces and lowest on the annular sectors. The windings of the crescent coil are desirably angled as shown in FIG. 11(b) so as to enhance flux confinement, thus, minimizing axial flux leakage and eddy currents in the magnet.

Other Reference Publication (1):
E.C. Wong et al., Magnetic Resonance in Medicine, vol. 21, 1 Sep. 1991, pp. 39-48.

Other Reference Publication (3):
J.P. Boehmer et al., Journal of Magnetic Resonance, vol. 83, 1 Jun. 1989, pp. 152-159.

Other Reference Publication (4):
Y. Bangert and P. Mansfield, J. Physics E 15, "Magnetic Field Gradient Coils for NMR Imaging," 235 (1982).

Other Reference Publication (5):
P. Mansfield and B. Chapman, J. Magnetic Resonance 66, "Active Magnetic Screening of Gradient Coils in NMR Imaging," 573-576 (Feb. 1986).

Other Reference Publication (6):
P. Mansfield and B. Chapman, J. Magnetic Resonance 72, "Multishield Active Magnetic Screening of Coil Structures in NMR," 211 (1987).

Other Reference Publication (7):
M.K. Stehling, R. Turner, P. Mansfield, Science 254, "Echo-Planar Imaging: Magnetic Resonance Imaging in a Fraction of a Second," 43 (1991).

CLAIMS:

1. An MRI gradient coil system substantially symmetric with respect to a 180.degree. rotation about a central axis, substantially symmetric with respect to a first plane perpendicular to said central axis, and substantially symmetric with respect to a reflection through a second plane containing said central axis, said system comprising:

a nonmetallic, nonmagnetic innermost gradient coilform cylinder of outer radius r.sub.g and inner radius r.sub.3 ;

electrically conductive elements bonded to the outer surface of said coilform cylinder;

a concentric inner cylinder of inner radius r.sub.1 and outer radius r.sub.2, where r.sub.2 is less than r.sub.3 ;

water sealing means between said cylinders at both ends thereof; and

plumbing means to permit fluid flow in the annular space between said cylinders.

2. The coil system of claim 1 in which said coilform cylinder is made from a material having thermal conductivity greater than 3 W/mK, elastic modulus greater than 12 GPa, and rupture strength greater than 100 MPa; said system further characterized such that (r.sub.g -r.sub.1 /r.sub.g is less than 0.1.

3. The system of claim 1 wherein the cylindrical coilform comprises silicon nitride.

4. The system of claim 1 wherein the cylindrical coilform comprises alumina.

5. The system of claim 1 wherein the cylindrical coilform comprises an alumina-filled composite.

6. An MRI gradient coil system substantially symmetric with respect to a 180.degree. rotation about a central axis, substantially symmetric with respect to a first plane perpendicular to said central axis, and substantially symmetric with respect to a reflection through a second plane containing said central axis, said system comprising:

a nonmetallic, nonmagnetic coilform cylinder of outer radius r.sub.g and inner radius r.sub.3 ;

electrically conductive elements bonded to the outer surface of said coilform cylinder;

a concentric inner cylinder of inner radius r.sub.1 and outer radius r.sub.2, where r.sub.2 is less than r.sub.3 ;

water sealing means between said cylinders at both ends thereof; and

plumbing means to permit fluid flow in the annular space between said cylinders,

in which said coilform cylinder is made from a material having thermal conductivity greater than 3 W/mK, elastic modulus greater than 12 GPa, and rupture strength greater than 100 MPa; said system further characterized such that (r.sub.g - r.sub.1)/r.sub.g is less than 0.1.

7. The system of claim 6 wherein the cylindrical coilform comprises silicon

nitride.

8. The system of claim 6 wherein the cylindrical coilform comprises alumina.

9. The system of claim 6 wherein the cylindrical coilform comprises an alumina-filled composite.

10. An MRI gradient coil system substantially symmetric with respect to a 180.degree. rotation about a central axis, substantially symmetric with respect to a first plane perpendicular to said central axis, and substantially symmetric with respect to a reflection through a second plane containing said central axis, said system comprising:

a nonmetallic, nonmagnetic innermost gradient coilform cylinder of outer radius r.sub.g, inner radius r.sub.3, thermal conductivity greater than 3 W/Km, and elastic modulus greater than 13 GPa;

electrically conductive elements bonded to the outer surface of said coilform cylinder;

a concentric inner cylinder of inner radius r.sub.1 and outer radius r.sub.2, where r.sub.2 is less than r.sub.3 ;

water sealing means between said cylinders at both ends thereof; and

plumbing means to permit fluid flow in the annular space between said cylinders.

11. The system of claim 10 wherein the cylindrical coilform comprises silicon nitride.

12. The system of claim 10 wherein the cylindrical coilform comprises alumina.

13. The system of claim 10 wherein the cylindrical coilform comprises an alumina-filled composite.

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